PB90-129339

Recent Advances in Risk Reduction Engineering

(U.S.) Environmental Protection Agency, Cincinnati, OH

1989

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/D-89/250	2.
3. RI PB90-129339	
4. TITLE AND SUBTITLE RECENT ADVANCES IN RISK REDUCTION ENGINEERING	5. REPORT DATE
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) John J. Convery	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, 26 West Martin Luther King Drive, Cincinnati, Ohio 45268	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Risk Reduction Engineering Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268	13. TYPE OF REPORT AND PERIOD COVERED Symposium Paper
	14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES
Presented at 1st Pan Pacific Cooperative Symposium on Industrialization and Emerging Environmental Health Issues, Kitakyushu, Japan, October 2-6, 1989

16. ABSTRACT

Contemporary environmental legislation such as the Comprehensive Environmental Response, Compensation and Liability Act of 1980 and the Superfund Amendment and Reauthorization Act of 1986 emphasize the reduction of risk of damage to the environment and human health as the basis of environmental management. There is a hierarchy of approaches to risk reduction including source control, reuse and recycle, treatment and exposure minimization. Recent examples of these approaches, which were evaluated by the Risk Reduction Engineering Laboratory, are presented including: Superfund innovative technology demonstrations, waste reduction techniques, protective clothing and an expert system to assess risk.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS (This Report) UNCLASSIFIED	21. NO. OF PAGES 14
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

RECENT ADVANCES IN RISK REDUCTION ENGINEERING

by

John J. Convery

Presented at

The First Pan Pacific Cooperative Symposium on
Industrialization and Emerging Environmental Health Issues
Risk Assessment and Risk Management
Kitakyushu, Japan
October 2-6, 1989

RISK REDUCTION ENGINEERING LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

RECENT ADVANCES IN RISK REDUCTION ENGINEERING

John J. Convery

Deputy Director, Risk Reduction Engineering Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

1. Introduction

The United States has spent over $700 billion for environmental cleanup and is currently spending $86 billion per year or about 2% of our Gross National Product on pollution control and regulation (Havens, 1989). Contemporary environmental legislation includes consideration of risk assessment, risk management and risk reduction. The Resource Conservation and Recovery Act (RCRA) of 1976 for example defines the technology requirements as being best demonstrated available technology (BDAT) for treating hazardous wastes. The criteria for available treatment includes treatment which (1) does not present a greater risk than land disposal, and (2) treatment which substantially reduces migration and toxicity as measured by the toxic characteristics leaching procedure (TCLP). Other significant environmental legislation such as the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) as amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA) emphasizes the reduction in risk of damage to the environment and human health as the basis of environmental management. The reduction of the risk can be achieved through a hierarchy of approaches as shown in Table 1. The historical reliance on land disposal and containment is being replaced by a preference for source control, treatment and destruction. The criteria for selecting a cleanup remedy for an abandoned hazardous waste (Superfund) site is shown in Table 2.

The National Academy of Sciences defined risk assessment as "the scientific activity of evaluating the toxic properties of a chemical and the conditions of human exposure to it in order both to ascertain the likelihood that exposed humans will be adversely affected and to characterize the nature of the effects they may experience" (Nat'l Acad., 1983). Risk assessment consists of four components including: 1) hazard identification, 2) dose-response evaluation, 3) human exposure evaluation, and 4) risk characterization.

Table 1. Risk reduction approaches

Type Of Risk	Risk Reduction Approach	Example
Environmental	Waste minimization	
	by Source Control	
	Material substitution	Plastic bead blasting
	Process change	Sulfuric acid anodizing
	Volume reduction	On-demand rinsing
	Treatment	
	Toxicity Reduction	Biological treatment
	Pollutant destruction	Thermal and chemical oxidation
	Media transfer and treatment	Vacuum extraction
	Containment and Immobilization	Solidification/ stabilization
Human Health	Personnel protection	Protective clothing
Technology Failure	Technology Demonstration	SITE program

Table 2. Superfund site remedy selection criteria

Short-term Effectiveness
- protect the local community during remediation
- protect the workers during remediation
- environmental impacts
- time to effect cleanup

Long-term Effectiveness and Permanence
- magnitude of long-term risk
- adequacy of controls
- reliability of controls

Reduction of toxicity, mobility and volume

implementability
- technical and administrative feasibility
- availability of services and materials

Cost
- capital
- operating

Compliance with applicable or relevant and appropriate requirement (ARARs) including chemical specific ARARs, action-specific ARARs and location-specific ARARs

Overall protection of human health and the environment

Regulatory acceptance

Public acceptance

Currently there are 1200 Superfund sites on the National Priorities List for cleanup with a potential 30,000 abandoned sites requiring remediation. A similar or larger number of currently operating hazardous waste treatment, storage or disposal sites may require corrective action under RCRA.

A recent analysis (Doty & Travis, 1989) of 50 Records of Decision (RODs) indicated that "compliance with ARARs and existing policies played a more significant role in deciding whether to remediate a site and cost appeared to play a more significant role in the selection of remedial alternatives than did risk." Selected recommendations of interest from the report included the need for development of more guidance in the areas shown in Table 3.

The Risk Reduction Engineering Laboratory conducts research and engineering studies of all risk reduction management approaches. This paper describes selected recent developments

Table 3. Needed area of risk assessment guidance

-analyzing food chain implications and assessing extent and magnitude of ecological risk
-delineating between actual risks and potential risks in risk assessments
-developing exposure scenarios and using groundwater modeling to predict future concentrations of contaminants
-determining cleanup criteria for soils (i.e., levels which are only protective of groundwater or levels which assume direct contact with contaminated soils)
-determining degree of risk reduction associated with remedial alternatives evaluated and outlining rationales for effectiveness of remedy selected

and risk reduction activities related to Superfund site remediation technologies, waste minimization techniques, protective clothing and expert systems.

2. Superfund Innovative Technology Evaluation (SITE) Program

The SITE program's demonstration component is a cooperative effort with private industry to encourage the development and use of more effective, permanent treatment technologies at Superfund sites and thereby reduce the risk associated with using untested technologies. EPA's role is to evaluate the performance of the technology and issue a Demonstration Evaluation Report and an Application Analysis Report which discusses the potential applications of the technology. The SITE program is two and one-

Thermal, Chemical and Biological Oxidation

The mobile Shirco Electric Infrared Incineration System was tested in Florida on PCB and lead contaminated oil refinery wastes and in Michigan to treat wastes containing paint sludges, solvents, PCBs, oils and greases, phenols and heavy metals. Average feed characteristics contained 272 ppm of PCBs and 778 ppm of lead. The unit uses silicon carbide rods suspended over a wire mesh conveyor belt to provide radiant heat up to 1850 degrees fahrenheit for 20 minutes in the primary combustion chamber. Gaseous volatiles are destroyed in a secondary combustion chamber operating at 2200 degrees fahrenheit for several seconds. In both tests the PCBs in the ash were reduced to less than 1 ppm with a destruction removal efficiency of greater than 99.99%. The lead remained in the ash; however, it was not immobilized as measured by the Extraction Procedure Toxicity (EPTox) and the TCLP tests. There is no definite evidence that the process reduces the mobility of heavy metals in the ash compared to the feed (EPA, 6/89).

The Pyretron Oxygen Burner was evaluated in a rotary kiln incinerator with a feed consisting of 60% contaminated soil with 2150 mg/kg of total organic carbon and 40% decanter tank tar sludge from coking operations. Principal organic hazardous constituents consisted primarily of polynuclear aromatic hydrocarbons.

Table 4: Completed site demonstrations

Developer	Technology	Location
Haztech	Infrared Incineration	Brandon, FL
Hazcon	Solidification	Douglassville, PA
Shirco	Infrared Incineration	Rose Township, MI
American Combustion	Pyretron Oxygen Burner	Jefferson, AR
Terra Vac	Vacuum Extraction	Groveland, MA
IWT/GEOCON	In-Situ Solidification	Hialeah, FL
CF Systems	Solvent Extraction	New Bedford, MA
Soliditech	Solidification	Morganville, NJ
Chemfix	Solidification	Clackamas, OR
Ultrox	UV/Ozone	San Jose, CA
Biotrol, Inc.	Aqueous biological	MacGillis & Gibb Site, MN
Biotrol, Inc.	Soil washing and biological	

Oxygen enhanced destruction efficiencies of POHCs exceeded 99.99% which was comparable to the air-only rotary kiln incineration performance. The oxygen enriched operation did achieve a doubling

of the waste throughput capacity compared to the air incineration operation (EPA, 4/89).

The Ultrox Technology uses hydrogen peroxide, ultraviolet light (UV) and ozone to oxidize toxic and refractory organics present in water at the parts per billion level to non-detectable levels. The technology was demonstrated in San Jose, California to reduce volatile organics (VOCs), polychlorinated biphenols (PCBs) and pesticides from a contaminated groundwater. VOCs detected at relatively high levels included acetone (160 ppb), 1,1-dichloroethene (180 ppb), 1,2-transdichloroethene (200 ppb), trichloroethene (920 ppb) and vinyl chloride (240 ppb). Data from a treatability study at the site indicated that the Ultrox Technology was capable of meeting the effluent limitations (2-5 ppb) for discharge to surface waters utilizing the following operating parameters: hydraulic retention time of 40 minutes, hydrogen peroxide dose of 25 mg/l, ozone dose of 75 mg/l, and a lamp density of three UV lamps of 65 watts each per square foot of reactor plan area (Lewis et al., 1989).

Two demonstration projects have been conducted in New Brighton, Minnesota at an active wood-preserving site where soil and groundwater has been contaminated with pentachlorophenol (PCP 60-100 ppm) and polynuclear aromatic hydrocarbons (PAHs 12 ppm) from creosote. Since 1970, a chromated copper arsenate process has been used for wood preservation.

The Aqueous Treatment System (ATS), developed by Biotrol, Inc. is a microbiological system, consisting of a layer of naturally occurring and added flavobacterium microbes growing on a plastic support material in tanks, used for degrading toxic organic compounds in water. Previous groundwater studies at the adjacent Bell Lumber and Pole Site showed that the ATS process reduced the PCPs to <5 ppm and the PAHs to < 0.5 ppm. The Biotrol Soil Treatment System (BSTS) which treated 75 tons of PCP and PAH (1500 ppm) contaminated soil consists of three technologies: a soil washer (SW); a slurry bioreactor (SBR); and the ATS. Slightly contaminated coarse soil particles are separated from heavily contaminated fine particles in the SW. The SBR reduces the contaminant concentration on the fine particles by treatment. Process water from the SW is recycled and treated in the ATS. Some 73% to 83% of the original soil was recovered as washed sand. PCP and PAH removals from the soil ranged from 85% to 99% (MPCA, 1989).

Solidification/Stabilization Processes

Solidification means encapsulation of the waste constituents whereas stabilization is the actual chemical reaction of the waste constituents and stabilization agents.

The SITE Program has completed four demonstrations of solidification/stabilization processes including Hazcon, Chemfix, Solidtech and International Waste Technologies each of which utilizes a proprietary additive to achieve the treatment objective. A summary of the treatment applications and performance of these technologies is shown in Table 5.

International Waste Technologies is an in-situ stabilization process which utilizes Geocon's deep soil mixing technology and an organophillic clay additive with a silicate-based cement. This technology eliminates the need to excavate the soil. The volume increase was 8.5%. Freeze/thaw cycles caused a loss of strength (EPA, 4/89).

Table 5: Summary of solidification/stabilization process characteristics

STABILIZATION/ TECHNOLOGY	SITE CHARACTERISTICS	UNCONFINED COMPRESSIVE STRENGTH (PSI)	IMMOBILIZATION METALS	ORGANICS	PERMEABILITY cm/sec x 10^{-7}
Chemfix	Transformer and metal salvage Pb - 1.8-11% PCB - 1.9%	Variable	Pb 93-100% Cu 95-99%	N.A.	3.6-12
Hazcon	Oil reprocessing metals - 2.3% oil/grease - 25%	200-1570	Pb - 100% or BNA	No VOCs	.01-0.1
Soliditech	Oil reprocessing Pb - .06-2% oil/grease-17% VOC 10-50 mg/l	390-860	Pb- 98%	Leachate Conc. unchanged ND	.09-4.5
International Waste Technologies	Heavy metals and PCB	300-500	Trend Metals	Trend PCB	2-28

Chemical and Vacuum Extraction

Harbor sediments ladened with PCBs at concentrations of 350 ppm and 2250 ppm were extracted with a propane/butane mixture to 10 ppm after ten passes and 96 ppm after six passes, respectively. The demonstration of CF Systems Corporation, two stage 20 bbl/day pilot solvent extractor and solvent separator

occurred in New Bedford, Massachusetts. The solvent which vaporizes in the extraction unit at reduced pressure is recompressed and recycled. The organics from the separator are recovered for disposal or reused off-site. The process can be used to treat a wide variety of organics (EPA, 4/89).

The Terra Vac in-situ vacuum extraction system was evaluated in Groveland, Massachusetts for the removal of volatile organic compounds. Some 95% of the contamination was trichloroethylene which occurred at concentrations of 250 ppm in the vadose zone of the soil. The soil had a porosity of 40-50%, a permeability of 10^{-4} to 10^{-8} cm/sec and a grain size of 10^{-1} to 10^{-3} mm.

A system of four, 24 feet deep barrier and extraction wells were used in conjunction with a vapor-liquid separator, vacuum pump and activated carbon adsorption system to remove the VOCs from the off gases. Some 1300 lbs of VOCs were extracted during the 56 day demonstration period reducing the soil gas concentration by more than 95% and the soil VOC concentration by as much as two orders of magnitude (EPA, 4/89).

3. Waste Reduction Innovative Technology (WRITE) Program

In the hierarchy of risk reduction techniques waste minimization or pollution prevention should be considered first followed by recycle and reuse, destruction and treatment and finally containment. Waste minimization opportunity assessments are the foundation for EPA's pollution prevention research activities. While each pollution generating activity is unique the use of the "Waste Minimization Opportunity Assessment Manual" (EPA, 1988) provides a systematic planned procedure with the objective of identifying ways to reduce or eliminate waste. Results of these assessments include promising options with the potential to reduce wastes within a specific waste stream and research needs for generic solutions. The WRITE Program is designed to expedite the use of waste minimization approaches in industry by demonstrating commercial and pilot scale innovative technologies. RREL funds the engineering evaluation and cost assessment in cooperation with industry. The following examples from General Dynamics were documented by PEI, Associates under contract to EPA.

A major new metals recovery system was installed to reduce wastewater flows to manageable rates. The cost of this system was $4.1 million. The system completely eliminated rinse tanks with a unique spray-rinse system contained in the transporter hoist unit, which travels over the plating bath tanks. Utilizing a computerized system, parts are rinsed only for a short period of time following immersion in a process solution. Rinse-water discharges from the operation were reduced from approximately 60 to 10 gpm.

A new automated sulfuric acid anodizing system with on-demand rinsing was installed to replace an old chromic acid anodizing system. The capital cost of the new system, which eliminated both water and air emissions of chromium, was $995,000.

A plastic bead blast stripper was installed to replace methylene chloride as a paint stripper at a cost of $18,000. This unit utilizes the reusable plastic beads in a mechanical stripping operation similar to sand blasting. The paint chips and spent plastic media are sent off site for incineration. This system eliminated the disposal of about 10,000 lb/yr of methylene chloride.

A robotic paint facility for the production paint operation was completed at a cost of $1.4 million. It includes computer-controlled robots; proportional paint mixing, which feeds preselected quantities of the individual paint components directly to the paint spray nozzle, thus, eliminating batch makeup operations; electrostatic spray guns; and automatic waste equipment cleaning solvent collection. In addition to reducing hazardous waste generated by the paint shop, air emissions were also reduced by 17 percent, from 12 to 10 tons per year. The use of robots also reduces worker exposure to paint VOC emissions.

The installation of four Freon recovery stills was completed at a cost of approximately $500,000. These stills process dirty waste Freon solvent from degreasing operations throughout the plant. Solvent purchases dropped by 35 percent in 1988, and should continue to decline substantially in 1989.

4. Personnel Protection Research

An estimated 300,000 to 500,000 single use protective clothing garments are used at Superfund sites annually. The annual cost for protective clothing is $7-9 million.

Section 5 of the Toxic Substances Control Act (P.L. 94-469) requires manufacturers and importers of new chemicals to submit premanufacturing notification (PMN) to EPA for review. The Agency's Office of Toxic Substances (OTS) reviews approximately 1800 PMNs annually. Those chemicals which are judged to be potentially toxic require assessments of the potential for human exposure during manufacturing, processing and end use. Protective clothing is one means of reducing dermal exposure risks. The RREL has supported the development of a model to predict the chemical penetration of a pure substance through clothing materials under continuous exposure (Bhoun, 1986). The model assumes Fickian diffusion of rate J, and the cumulative mass-permeatete((Q) as a function of time based on the diffusion coefficient, D, and the solubility S. OTS requires estimates of the time at which the cumulative amount penetrated reaches a limit of unacceptable human risk. The model requires input of the molecular weight, liquid density, vapor pressure and/or the functional groups of the PMN substance. A comparison of measured and predicted breakthrough times and steady state permeation rates for four test substances is shown in Table 6.

Table 6: Comparison of permeation data with permeation model predictions for natural rubber

Test Substance	Breakthrough Time (mins)		Steady State Permeation Rate (ug/cm^2-min)	
	Measured	Predicted	Measured	Predicted
Acetone	17	8	34	34
Cyclohexane	19	8	525	959
Isopropanol	5340	11	1	16
Toluene	10	21	782	792

Chemical protective clothing (CPC) must possess certain physical properties to function effectively as a barrier to chemicals. An evaluation of some 50 physical property tests was conducted on ten fabrics and three visor materials to define a recommended minimum battery of 11 tests which could be used in CPC garment specification and selection. The battery of recommended tests (Carroll & Schwope, 1988) included: puncture resistance, puncture propagation, abrasion resistance, bursting resistance, accelerating aging, electrostatic charge, impact resistance, deviation in line of sight, haze-abrasion resistance, and end point tests. Minimum acceptable values of these tests will depend on the specific application of the clothing. Further development of a cut test is recommended before it is added to the battery.

A new field method for measuring the chemical resistence of all types of clothing materials to single and multi-component liquid chemicals has been developed. The ASTM is considering adopting the method as a new standard. The new permeation cup procedure uses weight loss over time from an inverted cup of chemical which is covered with the clothing material. A field kit has been developed under a contract by Arthur D. Little. The unit should be very useful for determining the appropriate personnel protective clothing to select at emergency spill or hazardous waste sites (Carroll & Schwope, 1989).

5. Risk Assistant

EPA's Office of Health and Environmental Assessment is supporting the development of RISK ASSISTANT a microcomputer software program to facilitate assessment of hazardous waste sites. The system is being developed by the Hampshire Research Institute. It is suitable for a personal computer with 512K RAM, DOS 2.0 or later and requires 7.5 mega bytes of memory. Data entry includes a description of the site and an estimate or actual chemical contaminant concentrations. The system can be used to do the a variety of risk assessment tasks as shown in Table 7.

Table 7: Risk assistant capabilities

Evaluate health risks posed by hazardous waste sites.
Summarize risk information in a consistent format.
Store and retrieve exposure and risk assessment data.
Perform risk calculations.
Serve as a risk screening tool.
Develop sensitivity analysis.
Check exposure scenarios.
Reference risk information databases such as:
Integrated Risk Information System (IRIS)
Superfund Public Health Risk Evaluation Database (PHRED)
Federal and State regulatory standards
Chemical properties for environmental fate and transport.

6. Acknowledgements

The author wishes to express his appreciation to Ms. Lisa Brown for her contributions on waste minimization projects, Mr. Robert Olexsey, Mr. Steven James, Ms. Mary Stenson, and Ms. Norma Lewis for information on SITE Demonstration project reports, Mr. Michael Royer for information on personnel protection projects, Ms. Marian Olson and Mr. John Schaum for information on Risk Assistant and Ms. Lynn Davide and Ms. Doris King for typing this manuscript.

7. References

Congressional Testimony of Henry S. Havens, Assistant Comptroller, General Office of the Comptroller General, United States General Accounting Office before the Legislation and National Security Subcommittee on Government Operations, House of Representatives June 21, 1989 "Creation of a Department of Environmental Protection."

Doty, C. B. and Travis C. C., "The Superfund Remedial Action Decision Process" Office of Risk Analysis, Oak Ridge National Laboratory, Oak Ridge Tennessee, ORNL-6567, March 1989

In-Situ Vacuum Extraction-Demonstration Bulletin, EPA/540/M5-89/003, April 1989.

Lewis, N., Topudurti, K., and Foster, R., "A Field Evaluation of the UV/Oxidation Technology to Treat Contaminated Ground-water at a Hazardous Waste Site," to be presented November 1989.

Organic Extraction Utilizing Solvents-Demonstration Bulletin,EPA/540/M5-89/006, April 1989.

Shirco Infrared Incineration System - Application Analysis Report, EPA/540/A589/010, June 1989.

Site Demonstration of Two Technologies at the MacGillis and Gibbs Site: Fact Sheet, EPA and Minnesota Pollution ControlAgency, April 1989.

The Pyretron Oxygen Burner - Demonstration Bulletin, EPA/540/M5-89/008, April 1989.

Waste Minimization Opportunity Assessment Manual, EPA/625/7-88/003, July 1988.